

**Claims:**

1. A method for mapping  $m$  input bits to  $2^m$  modulation symbols of a two-dimensional symbol constellation, the method comprising:

forming a quarter-quadrant constellation of  $2^{m-4}$  modulation symbols that are located in a first quadrant of the two-dimensional signal plane, the quarter-quadrant constellation having one-sixteenth the size of the two-dimensional symbol constellation;

uniquely associating each modulation symbol of the quarter-quadrant constellation with a respective  $m-4$  bit label of the  $m$  input bits;

forming a quarter constellation of the two-dimensional symbol constellation by adding to the quarter-quadrant constellation three copies of the quarter-quadrant constellation rotated by  $-90$  degrees,  $180$  degrees, and  $-270$  degrees, respectively, and then displacing the quarter constellation by a shift value  $\Delta$  such that the symbols coincide with symbols of the desired two-dimensional symbol constellation, wherein the quarter constellation has one-fourth the size of the two-dimensional symbol constellation;

uniquely associating each symbol of the quarter constellation with a respective  $m-2$  bit label of the  $m$  input bits, wherein  $m-4$  bits of the  $m-2$  bit label are inherited from the quarter-quadrant constellation and two further bits of the  $m-2$  bit label are used to distinguish quarter-quadrants of the quarter constellation;

forming the two-dimensional symbol constellation by adding to the quarter constellation three copies of the quarter constellation rotated by  $+90$  degrees,  $180$  degrees, and  $+270$  degrees, respectively; and

uniquely associating each symbol of the two-dimensional symbol constellation with an

m-bit label, wherein m-2 bits of the m-bit label are inherited from the quarter constellation and two further bits of the m input bits are used to distinguish quarters of the two-dimensional symbol constellation.

5        2.        The method of claim 1, wherein of the two further bits of the m-2 bit label used to distinguish quarter-quadrants of the quarter constellation:

             a value of [00] corresponds to a first quarter-quadrant of the quarter constellation having the quarter-quadrant constellation;

             a value of [01] corresponds to a second quarter-quadrant of the quarter constellation  
10        having a quarter-quadrant constellation that has been rotated by -90 degrees;

             a value of [11] corresponds to a third quarter-quadrant of the quarter constellation having a quarter-quadrant constellation that has been rotated by 180 degrees; and

             a value of [10] corresponds to a fourth quarter-quadrant of the quarter constellation having a quarter-quadrant constellation that has been rotated by -270 degrees.

15        3.        The method of claim 1, wherein of the two further bits of the m input bits used to distinguish quadrants of the two-dimensional symbol constellation:

             a value of [00] corresponds to a first quadrant of the two-dimensional symbol constellation having the quarter constellation;

20        a value of [01] corresponds to a second quadrant of the two-dimensional symbol constellation having a quarter constellation that has been rotated by -90 degrees;

             a value of [11] corresponds to a third quadrant of the two-dimensional symbol

constellation having a quarter constellation that has been rotated by 180 degrees; and

a value of [10] corresponds to a fourth quadrant of the two-dimensional symbol constellation having a quarter constellation that has been rotated by -270 degrees.

- 5        4.        The method of claim 1, wherein:
- the two-dimensional symbol constellation is a 256-QAM constellation;
- the m input bits comprise eight bits  $[y^7, y^6, y^5, y^4, y^3, y^2, y^1, y^0]$ ;
- the  $2^{m-4}$  bits are bits  $[y^7, y^6, y^4, y^3]$ ;
- the two further bits of the m-2 bit label are bits  $[y^5, y^2]$ ; and
- 10        the two further bits of the m input bits are bits  $[y^1, y^0]$ .
5.        The method of claim 1, wherein:
- the two-dimensional symbol constellation is a 1024-QAM constellation;
- the m input bits comprise ten bits  $[y^9, y^8, y^7, y^6, y^5, y^4, y^3, y^2, y^1, y^0]$ ;
- 15        the  $2^{m-4}$  bits are bits  $[y^9, y^8, y^7, y^5, y^4, y^3]$ ;
- the two further bits of the m-2 bit label are bits  $[y^6, y^2]$ ; and
- the two further bits of the m input bits are bits  $[y^1, y^0]$ .
6.        The method of claim 1, wherein forming the quarter constellation further comprises
- 20        repositioning a plurality of quarter constellation symbol positions.

7. The method of claim 6, wherein:

the two-dimensional symbol constellation is a 128 QAM constellation;

the m input bits comprise seven bits  $[y^6, y^5, y^4, y^3, y^2, y^1, y^0]$ ;

the  $2^{m-4}$  bits are bits  $[y^6, y^4, y^3]$ ;

5 the two further bits of the m-2 bit label are bits  $[y^5, y^2]$ ; and

the two further bits of the m input bits are bits  $[y^1, y^0]$ .

8. The method of claim 6, wherein:

the two-dimensional symbol constellation is a 512-QAM constellation;

10 the m input bits comprise eight bits  $[y^8, y^7, y^6, y^5, y^4, y^3, y^2, y^1, y^0]$ ;

the  $2^{m-4}$  bits are bits  $[y^8, y^7, y^5, y^4, y^3]$ ;

the two further bits of the m-2 bit label are bits  $[y^6, y^2]$ ; and

the two further bits of the m input bits are bits  $[y^1, y^0]$ .

15 9. The method of claim 1, further comprising forming the m input bits from a plurality of information bits by operating upon the plurality of information bits to form a Forward Error Correction (FEC) frame.

10. The method of claim 9, wherein the FEC frame includes an integer number of trellis  
20 groups.

11. The method of claim 9, wherein Reed-Solomon encoding is employed to form the FEC

frame.

12. The method of claim 1, further comprising forming the  $m$  input bits from a plurality of information bits by:

5 Forward Error Correction (FEC) coding the plurality of information bits to produce a plurality of FEC blocks;

interleaving and randomizing the plurality of FEC blocks; and

appending a frame synch trailer to the plurality of interleaved and randomized FEC blocks to form a FEC frame.

10 13. The method of claim 9, wherein the FEC frame includes an integer number of trellis groups.

14. A method for mapping  $m$  input bits to a two-dimensional symbol constellation, the method comprising:

forming a quarter-quadrant constellation of  $2^{m-4}$  modulation symbols;

forming a quarter constellation of the two-dimensional symbol constellation by adding to the quarter-quadrant constellation three copies of the quarter-quadrant constellation rotated by -90 degrees, 180 degrees, and -270 degrees, respectively, and then displacing the constellation by a shift value  $\Delta$  such that the symbols coincide with symbols of the desired two-dimensional symbol constellation, wherein the quarter constellation has one-fourth the size of the two-dimensional symbol constellation; and

forming the two-dimensional symbol constellation by adding to the quarter constellation three copies of the quarter constellation rotated by +90 degrees, 180 degrees, and +270 degrees, respectively.

5      15.      The method of claim 14, wherein forming the quarter-quadrant constellation further comprises uniquely associating each symbol of the quarter-quadrant constellation with a respective m-4 bit label of the m input bits.

10      16.      The method of claim 14, wherein forming the quarter constellation further comprises uniquely associating each symbol of the quarter constellation with a respective m-2 bit label of the m input bits, wherein m-4 bits of the m-2 bit label are inherited from the symbols of the quarter-quadrant constellation and two further bits of the m-2 bit label are used to distinguish quarter-quadrants of the quarter constellation.

15      17.      The method of claim 16, wherein of the two further bits of the m-2 bit label used to distinguish quarter-quadrants of the quarter constellation:

        a value of [00] corresponds to a quarter-quadrant of the quarter constellation having an unrotated quarter-quadrant constellation;

        a value of [01] corresponds to a second quarter-quadrant of the quarter constellation  
20      having a quarter-quadrant constellation that has been rotated by -90 degrees;

        a value of [11] corresponds to a third quarter-quadrant of the quarter constellation having a quarter-quadrant constellation that has been rotated by 180 degrees; and

a value of [10] corresponds to a fourth quarter-quadrant of the quarter constellation having a quarter-quadrant constellation that has been rotated by -270 degrees.

18. The method of claim 14, wherein forming the two-dimensional symbol constellation further comprises uniquely associating each symbol of the two-dimensional symbol constellation with an m-bit label, wherein m-2 bits of the m-bit label are inherited from the quarter constellation and two further bits of the m input bits are used to distinguish quadrants of the two-dimensional symbol constellation.

19. The method of claim 18, wherein of the two further bits of the m input bits used to distinguish quadrants of the two-dimensional symbol constellation:

a value of [00] corresponds to a first quadrant of the two-dimensional symbol constellation having the quarter constellation;

a value of [01] corresponds to a second quadrant of the two-dimensional symbol constellation having a quarter constellation that has been rotated by -90 degrees;

a value of [11] corresponds to a third quadrant of the two-dimensional symbol constellation having a quarter constellation that has been rotated by 180 degrees; and

a value of [10] corresponds to a fourth quadrant of the two-dimensional symbol constellation having a quarter constellation that has been rotated by -270 degrees.

20. The method of claim 14, further comprising forming the m input bits from a plurality of information bits by operating upon the plurality of information bits to form a Forward Error

Correction (FEC) frame.

21. The method of claim 20, wherein the FEC frame includes an integer number of trellis groups.

5

22. The method of claim 20, wherein Reed-Solomon encoding is employed to form the FEC frame.

23. The method of claim 14, further comprising forming the m input bits from a plurality of  
10 information bits by:

Forward Error Correction (FEC) coding the plurality of information bits to produce a plurality of FEC blocks;

interleaving and randomizing the plurality of FEC blocks; and

appending a frame synch trailer to the plurality of interleaved and randomized FEC  
15 blocks to form a FEC frame.

24. The method of claim 23, wherein the FEC frame includes an integer number of trellis groups.



25. A transmitter comprising:

Forward Error Correction block that receives a plurality of information bits and that produces a plurality of FEC blocks;

an interleaver that interleaves the plurality of FEC blocks;

5 a randomizer that randomizes the plurality of FEC blocks;

a frame synch trailer block that appends a frame synch trailer block to the plurality of interleaved and randomized FEC blocks to form an FEC frame having a plurality of input bits; and

an encoder that maps  $m$  input bits of the plurality of input bits to a two-dimensional symbol constellation that that was constructed by:

forming a quarter-quadrant constellation of  $2^{m-4}$  modulation symbols;

forming a quarter constellation of the two-dimensional symbol constellation by adding to the quarter-quadrant constellation three copies of the quarter-quadrant constellation rotated by -90 degrees, 180 degrees, and -270 degrees, respectively, and then displacing the constellation by a shift value  $\Delta$  such that the symbols coincide with symbols of the desired two-dimensional symbol constellation, wherein the quarter constellation has one-fourth the size of the two-dimensional symbol constellation; and

forming the two-dimensional symbol constellation by adding to the quarter constellation three copies of the quarter constellation rotated by +90 degrees, 180 degrees, and +270 degrees, respectively.

26. An apparatus for mapping  $m$  input bits to  $2^m$  modulation symbols of a two-dimensional symbol constellation, the apparatus comprising:

means for forming a quarter-quadrant constellation of  $2^{m-4}$  modulation symbols that are located in a first quadrant of the two-dimensional signal plane, the quarter-quadrant constellation  
5 having one-sixteenth the size of the two-dimensional symbol constellation;

means for uniquely associating each modulation symbol of the quarter-quadrant constellation with a respective  $m-4$  bit label of the  $m$  input bits;

means for forming a quarter constellation of the two-dimensional symbol constellation by adding to the quarter-quadrant constellation three copies of the quarter-quadrant constellation  
10 rotated by  $-90$  degrees,  $180$  degrees, and  $-270$  degrees, respectively, and then displacing the constellation by a shift value  $\Delta$  such that the symbols coincide with symbols of the desired two-dimensional symbol constellation, wherein the quarter constellation has one-fourth the size of the two-dimensional symbol constellation;

means for uniquely associating each symbol of the quarter constellation with a respective  
15  $m-2$  bit label of the  $m$  input bits, wherein  $m-4$  bits of the  $m-2$  bit label are inherited from the quarter-quadrant constellation and two further bits of the  $m-2$  bit label are used to distinguish quarter-quadrants of the quarter constellation;

means for forming the two-dimensional symbol constellation by adding to the quarter constellation three copies of the quarter constellation rotated by  $+90$  degrees,  $180$  degrees, and  
20  $+270$  degrees, respectively; and

means for uniquely associating each symbol of the two-dimensional symbol constellation with an  $m$ -bit label, wherein  $m-2$  bits of the  $m$ -bit label are inherited from the quarter

constellation and two further bits of the  $m$  input bits are used to distinguish quarters of the two-dimensional symbol constellation.